CONFERENCE OF THE COMMITTEE ON DISARMAMENT

CCD/509
28 July 1976
Original: ENGLISH

LETTER DATED 28 JULY 1976 FROM MR. LEIF BLOMQVIST OF THE PERMANENT MISSION OF FINLAND TO THE SPECIAL REPRESENTATIVE OF THE SECRETARY-GENERAL TO THE CONFERENCE OF THE COMMITTEE ON DISARMAMENT TRANSMITTING A WORKING PAPER BY THE GOVERNMENT OF FINLAND

ON FINNISH CAPABILITIES OF SEISMOLOGICAL DETECTION OF UNDERGROUND NUCLEAR EXPLOSIONS

Following the decision of the Conference of the Committee on Disarmament to establish an Ad Hoc Group of Scientific Experts to consider international co-operative measures to detect and identify seismic events, I have the honour, upon the instruction of my Government, to forward to you herewith a working paper outlining "Finnish capabilities of seismological detection of underground nuclear explosions". I would be most grateful to you if the working paper could be distributed to the Members of the Conference of the Committee on Disarmament as an official document.

(Signed) Leif Blomqvist
Counsellor

WORKING PAPER BY THE GOVERNMENT OF FINLAND TO THE CCD

Finnish capabilities of seismological detection of underground nuclear explosions

As a consequence of its consistent support for the efforts to achieve a comprehensive ban of nuclear weapon tests, which it considers as one of the most important goals of present arms limitation negotiations, the Finnish Government has for a number of years endeavoured to make a contribution to the pursuit of an effective verification of such a treaty by seismological means.

Finland has actively taken part in co-operation with Danish, Norwegian and Swedish seismologists in the field of seismological detection (the so called Nordic Detection Club). Finnish seismologists have participated in seminars on detection seismology arranged in different Nordic countries and done research work in seismic institutions in Norway and Sweden. The Finnish Government therefore welcomes the Swedish proposal to form an expert group within the framework of the CCD to study t question of establishing a world-wide seismologic control network.

In its reply to the request of the Secretary-General relating to the creation a world-wide exchange of seismological data (United Nations General Assembly resolution 2604 A (XXIV)) Finland declared its preparedness to participate in such an exchange and gave detailed information on its national capabilities for doing so

Since that time Finland has increased its detection capability both technologically and in research.

During the past five years the development of methods and means for seismic verification in Finland has endeavoured to elaborate new event identification techniques, to demonstrate and map the favourable seismic recording conditions prevailing in most of Finland, and to design and construct a new small-scale array station producing digital data from short-period seismometers, which are located at as great a distance as possible from cultural noise disturbance. In addition the several conventional high-quality stations in Finland are making data internationall available for use in seismic research.

Research on seismic event identification

Since 1972 a study has continued on the use of waveform and spectrum of the seismic P-wave for event classification. In spite of the demonstrated superiority of the M_s:m_b discriminant employing both body waves and surface waves it is felt th there are several reasons for continuing to develop new discriminants independent f the M_s:m_b. The combination of several independent discriminants increases the

discrimination ratio. The problem of having mixed signals is less common for P-waves than for surface waves, and evasion of identification might be more difficult when several different discriminants are used. The new discriminants should preferably have a clear physical meaning related to the difference of explosion and earthquake sources.

Most of the suggested P-wave discriminants have employed two characteristics of the P-wave signal, its complexity and its spectral contents. Of these two the use of spectral contents seems to be less susceptible to evasion by exploding multiple explosions, and to have a better discriminating capability according to several studies. The explosion source which has the smaller dimensions in space and time sends out P-waves which have a higher cut-off frequency, i.e. a broader spectrum than that of the earthquake generated P-waves. Our study shows (ref 1) that the significant regional variation of the absorption of high-frequency seismic waves in the Earth can regionally modify the spectrum of P-waves. Use of any spectral discriminant employing energy up to frequencies of several H_z then requires extensive regionalisation, which may be difficult to achieve.

To use the spectral properties of the P-waves for discrimination as low frequencies as possible should be used. The optimum range appears to be 0.2 to 2 H_z. An approach which was studied (ref 2) was to make a correction for the recording distortion in an as broad frequency range as possible and then to compute the width of the primary P-wave pulse on the resulting trace. Since a broad-band seismograph was actually simulated the measurements were made in the suitable frequency band and the sensitivity to variation of absorption decreased. The capability to separate earthquakes and explosions was slightly inferior to the M_s:m_b discriminant. For one set of events having a wide geographical variation, depths less than 100 km and in the magnitude range 4.5 to 6.1 (m_b), out of 41 earthquakes 38 were classified as earthquakes, 2 were marginal and for 1 no measurement could be done. All 10 explosions were correctly classified.

The broadening of the frequency band worsens the signal to the noise ratio. The described broad-band measurements were done using data recorded by short-period seismographs at the large seismic arrays, such as the NORSAR array in Norway utilizing the signal to noise enhancement achieved in aligning and summing signals from over 100 sensors. The body wave (m_b) magnitude at which for 90 per cent of the detected events occurring at that magnitude the measurements could be made, was observed to be 4.5 plus or minus 0.2.

Determination of the characteristic event duration from the width of the P-wave pulse through broad-band signal measurements appears to offer possibilities of defining a usable discriminant, sufficiently independent of the M_s:m_b discriminant and applicable to magnitudes low enough, that it may be used in combination with the M_s:m_b. Special broad-band instrumention may not be necessary, more important may be the capability of a large seismic array to suppress ground noise. We thus anticipate further progress in the field of event identification.

Recording conditions and the new short-period array in Finland

In a recent study (ref 3) the event detection capabilities of conventional seismic stations in Fennoscandia were estimated. Using the events and magnitudes reported by an international center, it was determined for each event whether or not the station in question had detected the event in question. Thus a detection curve was obtained, giving the probability of detection at a given magnitude. The best detection capability among the stations studied was reached by a station in central Finland. For events in the teleseismic range the 90 per cent incremental detection threshold, i.e. the body wave magnitude (m_b) at which 90 per cent of the total events occurring at that magnitude are detected, was for that station 5.1. The 50 per cent threshold is 4.5. The study concluded that the detection capability generally increases (the noise level decreases) with increasing distance from the North Atlantic Ocean, the stations at or near the ocean coast having 90 per cent detection thresholds from 5.8 to 6.1. In another study (ref 4) it was shown that to achieve optimum detection capability, a station should be situated at least 150 km away from the shores of the Baltic Sea or its gulfs.

In a study using data from arrays in Fennoscandia (ref 5) it was concluded that the heterogeneity of the crust and upper mantle is somewhat less in southern Finland situated in the eastern half of the Baltic shield, than at the western boundary of the shield. The conditions of array operation improve somewhat with a decreasing degree of heterogeneity.

A new small short-period seismic array has been constructed on a site in central Finland fulfilling the noise criteria and supposed to be geologically homogeneous. The array began test operation in the autumn 1975. It employs digital radio link transmission and has a very compact instrumentation designed and built in Finland using C-MOS integrated digital circuits. Since the number of sensors is small (though the array diameter is over 100 km) usual array processing would give only a small signal to noise enhancement. Records given by each sensor were analysed

separately and for events in the teleseismic range (30-90 degrees) the 90 per cent and 50 per cent incremental detection thresholds were found to be 4.7 and 4.0 (m_b), respectively. Some form of array processing may slightly improve these figures, which in any case are preliminary.

Special care has been taken to ensure a broad dynamic range in recording. Due to its good detection capability the array is expected to be able to make a useful contribution, even in an international framework, to detection and location of small seismic events. A later implementation of long-period or broad-band seismographs is planned.

A detailed study has been made on several storms of microseisms, or ground noise (ref 6). Long-period data from a large seismic array were used. Such studies may be useful for mapping the temporal and directional variation of the long-period noise limiting the surface wave detection capability.

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